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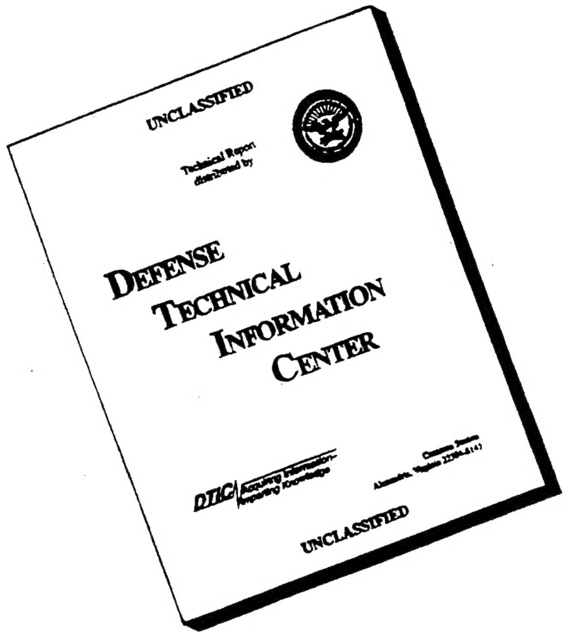

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This instrumentation project has provided the physics department at NCCU with an opportunity to assemble a broad band spectrometer in the millimeter and submillimeter wave region to perform high resolution spectroscopy. The central component for the generation of radiation is a backward wave oscillator (BOW) in the frequency region 110 Ghz to 180 GHz with the output power of ten's of milliwatts. It has an option of generating higher frequencies by using doubler and tripler, or by an conventional multiplier, still with power in the order of milliwatts.
A system based upon this BWO including a highly sensitive fast liquid helium cooled InSb detector, combined with state-of-the-art data acquisition hardware and labview software package from National Instruments, will gradually replace our dependence on the existing broadband spectrometer, reducing the downtime of the old system and increasing the productivity in terms of data collection . The new system has the potential for application to other research areas where the strength of the radiation is an important factor along with its resolution. Its higher output power and good resolution will make it useful in both gas and solid phase spectroscopy. Preliminary results regarding its performance characteristics are presented below. Various equipment purchased through this grant are listed below (Table 1).

Backward wave oscillators (BWOs) have been used in a number of system configurations for high resolution spectroscopy in the millimeter and submillimeter spectral region. These have included free running, cavity locked, and phase locked configurations. The NCCU spectrometer has been constructed based on a free running configurations and a fast, sensitive InSb liquid helium temperature detector. The high spectral resolution and accuracy of this system is derived from the excellent short term spectral purity of the BWO and the fast frequency scan which effectively freezes the long term drift. Calibration is derived from the etalon fringes and reference lines.

The frequency -voltage characteristics of the BWO (model OB-86) is shown in Figure 1. Frequency sensitivity shows to be on the average around 75 MHz/volt. The frequency calibration is performed using a scheme shown in Fig. 2. The beam splitter splits the millimeter wave into two paths. One part goes to the absorption cell while the other part is directed to a high resolution Fabry-Perot cavity. The spectral signal due to HNO_3 and the etalon signal is shown in Fig. 3. The result of the frequency calibration shows resolution to be around 100 KHz (Figure 4) which is compatible to our older frequency-multiplier based broadband spectrometer.

Table 1

List of Equipment

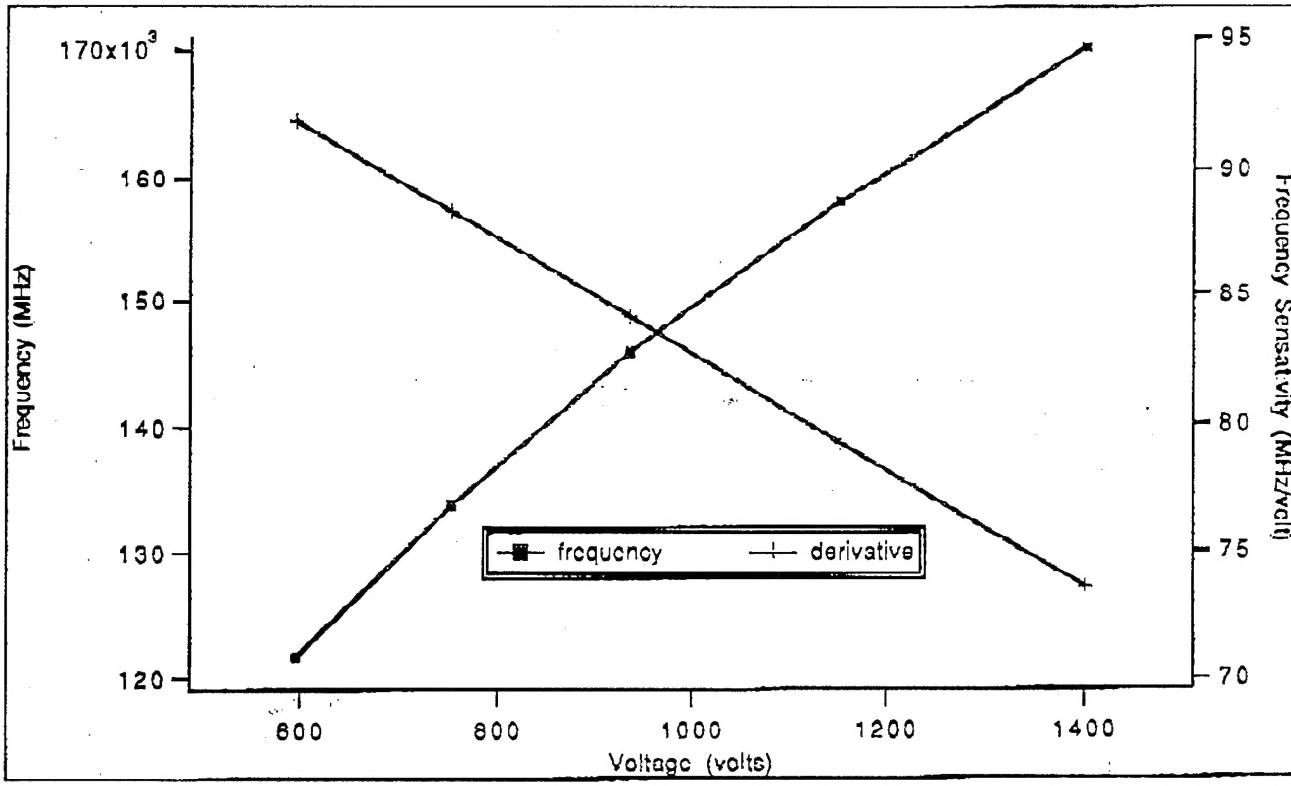
1. Microwave Signal Generator - free running, sweepable millimeter source:
   Packetized 115-178 GHz Backward Wave Oscillator (BWO) from ISTOK, 3 KV power supply, sweep unit, gas cell and Fabry-Perot cavity for frequency calibration, and optics.
   (Items #s 1,2, and 6 of the original budget)

2. Digital Storage Scope- Mac based data acquisition and control system:
   General purpose I/O Board (National Instruments NB-MIO-16L-9), DMA Board (National Instruments NB-DMA2800), Labview software package, custom made software, multi media computer with high resolution monitor, and a hard copy output printer.
   (Item # 5 of the original budget)

3. Submillimeter detector- Dual submillimeter detector:
   Liquid helium dewar, InSb detector elements, preamplifiers and amplifiers, bias box, horns, light pipes, and other optics.
   (Item # 3 of the original budget)

4. Portable pumping station:
   Balzers Turbomolecular Drag Pump, model TMH 260, 210 l/sec, Power supply and other accessories, Leybold direct drive mechanical pump.
   (Item # 4 of the original budget)

OB-86 tube characteristics



Point	fit	variables	diff	frequency	voltage	derivative
0	121790	105.36	-166.781	121624	596	91.846
1	133530	-0.022674	255.938	133785	753	88.286
2	145866		82.3906	145947	937	84.114
3	158388		-280.031	158107	1153	79.216
4	170157		108.766	170267	1401	73.593
5						

Figure 1

General Idea

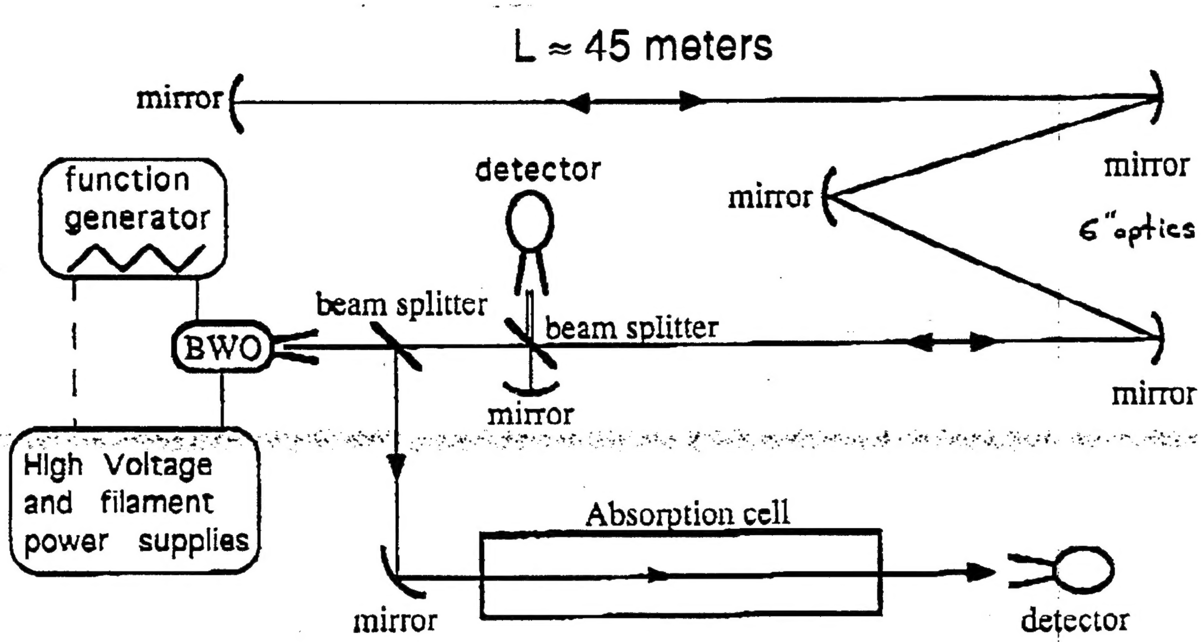
Split BWO power into two/three paths
(Simultaneously recorded)

→ **Sample Gas Absorption Cell**

→ **Etalon Interferometer**
Use interference pattern as reference frequency markers

→ **Reference Spectrum**
Calibrate the frequency markers

BWO Etalon Spectrometer

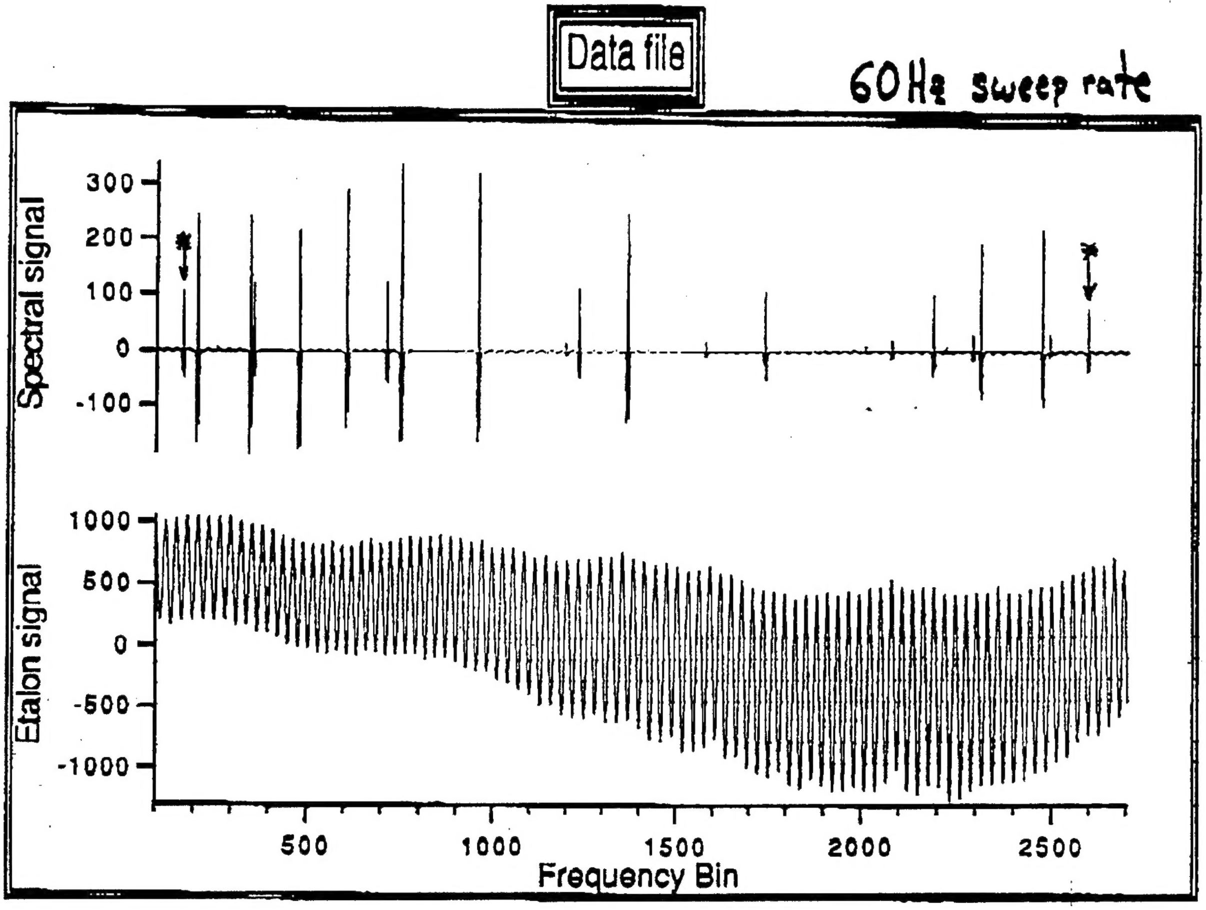


$$\text{Interference Amplitude} \propto \sin\left(\frac{2\pi L}{c}\nu\right)$$

$$\text{Period} \approx \frac{300}{L}\ \text{MHz}$$

L = Path Difference (meters)
c = Speed of light
ν = Frequency

Figure 2



$\Delta = 3.3723$ MHz $\Rightarrow$ $L = 44.449$ meters

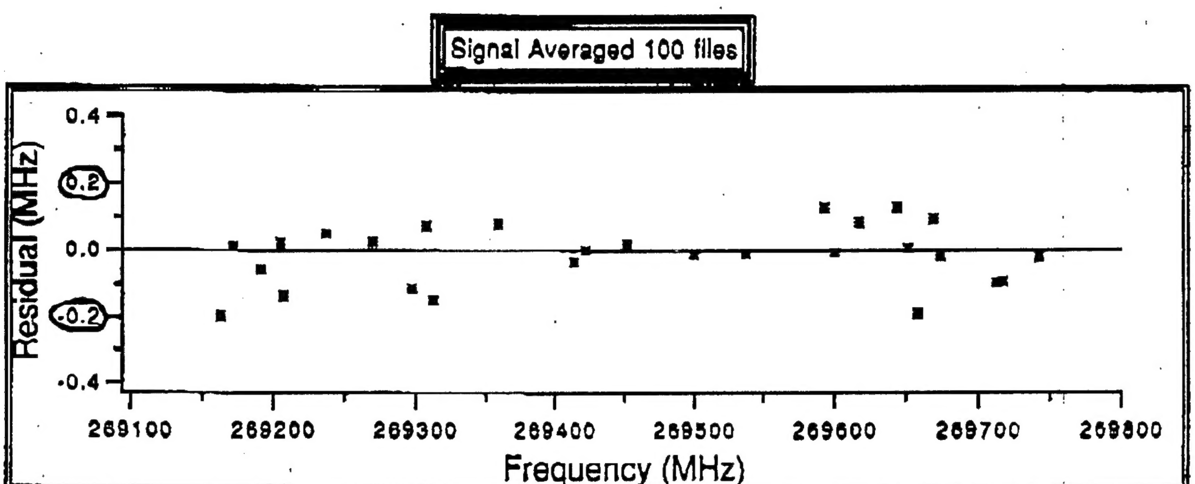
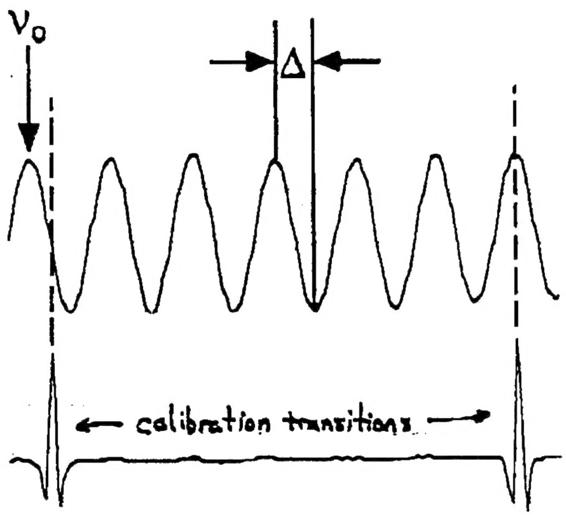


Figure 3

Frequency Calibration



⟹ determine Δ and ν_0

L ≈ 50 meter → Δ ≈ 3 MHz

Resolution ≈ 100 kHz/bin (number of points ≈ 30)

Sampling rate = 2 µs

Frequency marker occurs every 60 µs

Time to sweep 100 GHz ≈ 2 seconds

Assumptions:

Tube is linear over 3 MHz and 60 µs (16 kHz "bandwidth")

➡ linear interpolation between minama and maxima

- Fundamental tube characteristics - Impedence mismatching, Vane imperfections
- Voltage noise, temperature drifts, cathode - ac filament coupling (time dependent)

Determine $V_{BWO}(t)$ ⟹ calibrate frequency of the spectra

Figure 4